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FARMERS' PREFERENCES, SEED SOURCE, PRODUCTION CONSTRAINTS AND IMPROVEMENT NEEDS ASSESSMENT OF BAMBARA GROUNDNUT (*VIGNA SUBTERRANEA* [L.] VERDC.) IN NORTHERN RURAL OF NAMIBIA

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Abstract

Bambara groundnut (Vigna subterranea [L.] Verdc.) is one of the neglected and underutilized legume crops grown by resource-poor smallholder farmers in sub-Saharan Africa (SSA). Its potential has been neglected for years by researchers and hence has remained an orphan crop. The objectives of this study were to assess preferences, seed availability, crop improvement needs and production challenges faced by Bambara groundnut farmers in Namibia. A cross-sectional survey comprising 100 randomly selected farmers was conducted in five of the eight northern regions of Namibia. Results showed that large seed size, cream seeds, early maturity, and drought-tolerant are the main farmer-preferred traits. Okaongoti was the most preferred (20%) variety. The primary seed sources are own saved seed (61%) and a combination of informal market and own saved seed (25%). The major production constraints of Bambara groundnut were insect pests, low yield and lack of improved varieties. Breeding of Bambara groundnut varieties with the farmer-preferred traits is vital to improving its yield level and overcome production challenges in the country

Key words**:** *farmer-preferred traits, Bambara groundnut, orphan crops, subsistence farming*

INTRODUCTION

Bambara groundnut (*Vigna subterranean* (L.) Verdc.) is an orphan, underutilized and less exploited legume crop in Africa and beyond. It is an edible grain legume crop indigenous to sub-Saharan Africa (SSA), playing vital socio-economic roles in the sub-continents semi-arid areas [16]. Bambara groundnut originates in West Africa, but the crop is currently grown in many African countries [11]. In Africa, it is ranked as the third most important legume after cowpea and groundnut [24].

Bambara groundnut is used as food and feed crop [22]. It is highly nutritious, containing 65% carbohydrate, 18% protein and 6.5% fat content [33]. The protein in Bambara groundnut might be a solution to malnutrition, making it a valuable food for poor people who cannot afford expensive animal protein in developing countries [32]. Bambara groundnut is of agronomic importance because of its ability to fix nitrogen in the soil, and therefore, suitable for low input production system [13]. Bambara groundnut being drought tolerant, can survive harsh environments and survive extreme heat. Different countries use Bambara groundnut in different ways; in Senegal, it is used for medicinal purposes in addition to food [29].

Despite its numerous benefits, Bambara groundnut has been ignored by research and conservation entities [14] and hence remains marginalised and underutilised. Currently, there are organisations such as Africa Center for Crop improvement, BamNetwork project, Crops For the Future, African Orphan Crops Consortium, and others are making an effort to research on the crop [10]. [19], reported that women in Mali sell Bambara groundnut to earn income. In Namibia, the crop is commonly used for human consumption, livestock feed and income generation [31].

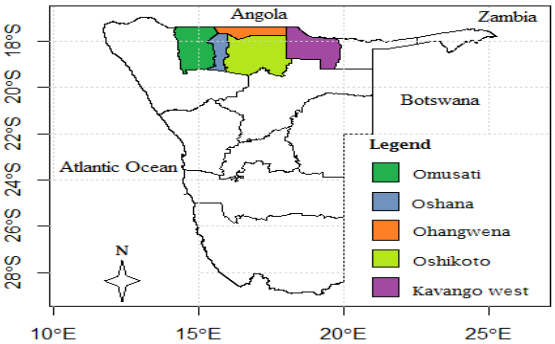
In sub-Saharan Africa, agricultural production is limited by water scarcity, lack of improved crop varieties and loss of genetic diversity [17], increasing dependence on a few crops for food. In Namibia, the crop is mainly grown in northern areas of the country where

it is ranked the second most important legume after cowpea [31, 8]. Through many years of successive cultivations, farmers have selected Bambara groundnut landraces with preferred traits, such as high yields, bunch type and other traits [1]. The seed production and marketing system of this crop is not formalised as farmers are still acquiring seeds informally by using their own seeds from the previous harvest [5]. Agricultural research on breeding of Bambara groundnut focused on selection between and within-population of landraces for yield performance, disease resistance and drought tolerance rather than other variables [9].

Bambara groundnut varieties exist as landraces, which are informally classified and named according to performance, colour and areas of production. As a result, a single accession may be produced under different names or vice versa [18]. Therefore, any breeding program should be farmer-preferences centred for easy adoption of released varieties. Undertaking a needs assessment study to find out what farmers have on their farm regarding Bambara groundnut preferences on the crop, production constraints and what they would rather have as an improvement is critical in guiding a successful breeding program. Therefore, the present study assessed farmers preferences, seed conservation and production constraints in Northern Namibia.

MATERIALS AND METHODS

Site description



Map 1. Map of Namibia showing the study area Northern Namibia
Source: Produced by author using ggplot package for R-statistics, Shapefiles obtained from GADM.

The needs assessment survey was conducted in five regions in northern Namibia, namely, Omusati, Oshana, Oshikoto, Ohangwena, and Kavango West (Map 1). Average annual rainfall in the study area ranges from 450–600 [3] and average minimum and maximum temperature is 23–39°C.

Questionnaire design and sampling

A cross-sectional survey was undertaken in July 2018. The questionnaire comprised both closed and open-ended questions. A total of 100 households (male and female-headed households) were involved in the survey. The sample was selected using a four-stage probability sampling methodology.

First stage involved a purposive selection of the regions. The regions also served as the primary domain of estimation.

Second stage was the selection of a single constituency from the regions using a simple random sampling technique.

Third stage involved the selection of villages within the constituencies using the simple random sampling technique.

Fourth and, the final stage was the selection of the households from the villages in stage three.

Table 1. Distribution of sampled household sizes by region and constituency

Region	Number of households*	Constituency	Households sampled
Omusati	54,383	Anamulenge	20
Oshana	44,544	Okatana	20
Ohangwena	49,470	Ondobe	20
Oshikoto	45,407	Omuntele	20
Kavango west	17,046	Kapako	20
Total	**210,850**		**100**

* Number of households are estimated as determined by the national demographic survey of 2016.
Source: Computed by author based on the summary data from the National demographic survey of 2016 by the Namibia Statistical Agency.

Table 1 above summarises the sample type per each of the 4-stage subset of the multistage probability sampling scheme.

A sample size of 100 was determined using the last column of Table 2 below and based on e total population of 210,850 households to

attain a 10% error margin. Then 100 household sample size was then allocated using similar allocation scheme under stratification, with the region as the bases for stratification.

Table 2. Extract of sample sizes for selected error margins with 95% fiducial limits and p = 0.5 based on the formula of Yamane (1964).

Size of population	Sample size (n) for Precision (e) of:			
	±3%	±5%	±7%	±10%
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	100
>100,000	1,111	400	204	100

Source: Computed by the author using Yaro Yamane formula of 1964.

Validation of survey instrument

A total of 15 questionnaires were administered as a pilot to check the test items for consistency. No modification was done, and hence the pilot data was added to the overall sample

Data collection and analysis

Data on preferred traits, variety, seed color, seed source and constraints on Bambara groundnut production were recorded using a questionnaire. Descriptive statistics in the form of graphical presentation, cross-tabulation, and frequencies were used to address the objectives of the study. Non-parametric test of association/dependence was conducted using Pearson's Chi-squared test.

RESULTS AND DISCUSSIONS

Socio-demographic information of the farmers

The study focused on Bambara groundnut farmers' preferences of landraces used in the selected five northern Namibian regions. A cross-tabulation of regions by socio-demographics revealed a significant association between region and age (χ^2 = 23.628; P < 0.023). Thirty-one per cent (31%) of those interviewed are between the age of 46 and 60 years, 30% are above 60 years, 27% are between 31 and 45 years, while 12% aged between 15 and 30 years. The age category (46–60 years) of the respondents may have been attributed to the fact that most of the young people migrated to urban areas to search for jobs. In contrast, older people remained in rural areas carrying out farming activities. The chi-square test indicated a significant association between region and education (χ^2 = 42.935; P < 0.001). No association is detected amongst gender, marital status, household size, number of adults and owner of the house (Table 3).

Table 3. Socio-demographic of interviewed Bambara groundnut farmers

Variables		**%**	**df**	χ^2	***P*-value**
Gender	Male	9	4	6.593	0.159
	Female	91			
Age	15-30	12	12	23.628	0.023
	31-45	27			
	46-60	31			
	≥61	30			
Marital Status	Single	41	8	8.018	
	Married	48			0.432
	Widowed	11			
Education level	None	15	12	35.798	0.000
	Primary	28			
	Secondary	56			
	Tertiary	1			
Household size (Number of children/family)	≤10	94	8	8.362	0.399
	11-20	5			
	≥21	1			
Household size (Number of adult/family)	≤10	90	8	9.528	0.300
	11-20	8			
	≥21	2			
Owner of the house	Man	59	8	6.051	0.641
	Woman	41			

Source: Author survey data (2019).

The demographic findings indicated that 91% of females and 9% of males are interviewed. Many farmers interviewed were females, possibly because Bambara groundnut is believed to be a women's crop. This finding was in agreement with those of [6, 12]. The study found that 56% of the farmers interviewed had attended secondary school hence literate. Primary school leavers were 28% as compared to 12% who had not attended school as a result, they knew the

importance and benefits of using improved seeds according to their preferences. The total number of households in the five regions comprised 94% children, who could be fed with Bambara groundnut because it is rich in protein, carbohydrate, and fat. Hence it can be a substitute for meat [22] The marital status showed that 48% were married, 41% were single, while 11% were widows. Further, 59% of the respondents indicated that men headed households.

Bambara groundnut farmer-preferred traits

Farmers gave multiple responses about preferred traits. Farmers in the surveyed area preferred particular Bambara groundnut based on different traits such as seed size, seed coat colour, maturity, taste, and pods with two or more seeds. The preferred traits showed significant association (χ^2 = 58.852, P < 0.066) between regions and traits. Seed size depicted the highest percentage (57%) of preferences as large-sized seeds were most preferred (Table 4). The same results obtained in Nigeria by [21]. The results can also be compared with some findings in Malawi, where farmers preferred small-seed Bambara groundnut for relish and big seeded Bambara groundnut for snacks [27]. However, in this study, the preference of seed size was not linked to any use except to high yield. High yield was the most preferred Bambara groundnut trait, and large-sized seeds could be one of the traits that correlate with high yield due to their mass. Hence, farmers need to have a high-yielding crop to produce a surplus for household consumption and income generation [15]. The combination of seed colour and seed size was preferred by 13% of the Bambara groundnut growers. Farmers also indicated drought tolerance as Bambara groundnut is regarded as a drought-tolerant crop compared to other legume crops and maturity as some of the preferences. Early maturity was favoured by 7% of the farmers. Maturity is essential in terms of not only giving an early harvest but also in escaping drought, which is a common phenomenon in arid and semi-arid regions such as Namibia [18] Other preferences ranged from 1–6%, indicating that the traits were less important to farmers (Table 4). Farmers expressed other preferences such as high yield, big leaves, thick pods, yellow pods, seed shape, bushy type, medium leaves, and nitrogen fixation. Farmers indicated that Bambara groundnut crops with big leaves is likely to give big pods and high yield. Also that bambara groundnut cultivars with big leaves because of their higher fodder yield for livestock [12, 30].

Table 4. Farmers' main preferred traits in five regions of northern Namibia

Traits	**Region**					**%**
	Omusati	Oshana	Oshikoto	Ohangwena	Kavango West	
Seed colour (SC)	1	1	2	2	0	6
Seed size (SS)	12	9	7	13	16	57
Maturity (M)	2	2	1	1	1	7
Pods with 2 or > seeds (P)	0	0	1	0	0	1
SS + M	0	0	3	0	0	3
SC + SS	4	5	2	0	2	13
SC + SS+ M	0	0	2	0	0	2
M + P	0	0	0	1	1	2
SC + SS + M + P	1	0	1	0	0	2
SC + taste	0	2	1	1	0	4
SC + SS + taste	0	1	0	0	0	1
SC + taste	0	0	0	2	0	2
Total number of farmers	20	20	20	20	20	100
χ^2						58.852
Df						44
P-value						0.066

Source: Author survey data (2019).

Farmer-preferred cultivars

Cultivar preferences appeared to be region-specific and are significantly different (P < 0.000). Results showed that farmers had specific preferred cultivars which they cultivate and were named according to colours

and performance. **S**ignificant association (χ^2 = 138.86; P = 0.000) among different cultivar grown across the five regions are detected (Table 5). The cultivars which are grown in north-central regions (Omusati, Oshana, Oshikoto and Ohangwena) are given local names such as Engowa, Okambishi, Egogani, Okaongoti, Olunya, and Onkwaya [8]. In this regard, Okaongoti was 42% popular, followed by Olunya (25%) and Okambishi (23%). In one north-eastern region (Kavango West), cultivated seed types were described using colours. In this regard, 49% of the respondents showed that the cream seed is popular, followed by both black and red (21%). The farmers' response suggested that the most preferred are cream-seeded cultivars in the study regions Farmers preferred cultivars were named according to colours and performances [1]. Therefore, in the absence of a breeding program, farmers will continue with the traditional selection that may lead to loss of good cultivars. Since Bambara groundnut farmers had their preferred traits, and not all cultivars have high-quality traits that farmers need, crop improvement is required to fill this gap.

Table 5. Preferred cultivar in North-central and Kavango West of Namibia

	Region	**Omusati**		**Oshana**		**Oshikoto**		**Ohangwena**		**Kavango West**	
	Class	O	E	O	E	O	E	O	E	O	E
Cultivars	Olunya	0	2	8	2	4	2	0	2	0	2
	Engowa	0	0	2	0	0	0	0	0	0	0
	Egogani	0	0	2	0	0	0	0	0	0	0
	Okambishi	1	2	2	2	6	2	2	2	0	2
	Okaogonti	12	2	0	2	4	2	4	2	0	2
	Onkwaya	0	0	1	0	0	0	0	0	0	0
	Tan	0	0	0	0	0	0	0	0	2	0
	Red	1	2	1	2	3	2	0	2	5	2
	Maroon	0	0	0	0	0	0	0	0	2	0
	Black	0	2	1	2	2	2	4	2	3	2
	Cream	3	5	1	4	1	5	10	5	8	5
	No idea	3	3	2	3	0	3	0	3	0	3
	Total	20	20	20	20	20	20	20	20	20	20
	df									44	
	χ^2									138.9	
	P-value									0.000	

Source: Author survey data (2019), O is the observed frequency and E is the expected frequency computed as the row total by column total divided by the grand total.

Bambara groundnut seed source and selection

Seed source is not significant ($P < 0.204$) to farmers in all regions studied. Results showed that many farmers (61%) obtained their seeds from the previous harvest. Twenty-five per cent (25%) of farmers acquired seeds both from the open market and from the previous harvest (Table 6). Farmers in the study area are using unimproved cultivars sourced from informal market, neighbour and relatives. The informal acquiring of seeds, it might be due to the informal nature of seed exchange among farmers coupled with the recycling of the seeds by the farmers, which might lead to a slight genetic erosion since the crop is self-pollinated. This result is in line with the results presented by [12, 23]. However, [25] reported that farmers from Burkina Faso also obtain seeds from the previous harvest. They further stated that seeds sown were mixed and environmental conditions of each year could favour one or some accessions to the detriment of others, hence only adapted accessions will produce more progenies. So, the composition of seed will change from year to year according to previous environmental conditions. [2] results also showed that farmers' selected seed for the following season based on seed and cultivar traits such as seed colour, seed size, taste, early maturity and, to some extent, based on pods with two

or more seeds, among others. Chi-square test indicated that there was a highly significant association (χ^2 = 57.271; $P \leq 0.000$) in seed selection criteria among the regions. Seed size was considered to be the most important criterion, followed by seed colour and size; seed colour, taste, seed size and then by other axillary criteria such as maturity and yield (Figure 1).

Table 6. Bambara groundnut seed source in five northern regions of Namibia

Seed Source	Region					%
	Omusati	Oshana	Oshikoto	Ohangwena	Kavango West	
Own seed (OS)	13	16	5	10	12	61
Open market (OM)	0	1	0	3	1	5
Neigh bour (N)	0	1	3	1	0	5
OS + OM	6	1	5	6	7	25
OM + N	1	0	1	0	0	2
OS + N	0	1	0	0	0	1
OS + OM + N	0	0	1	0	0	1
Df						24
χ^2						29.433
P-value						0.204

Source: Author survey data (2019).

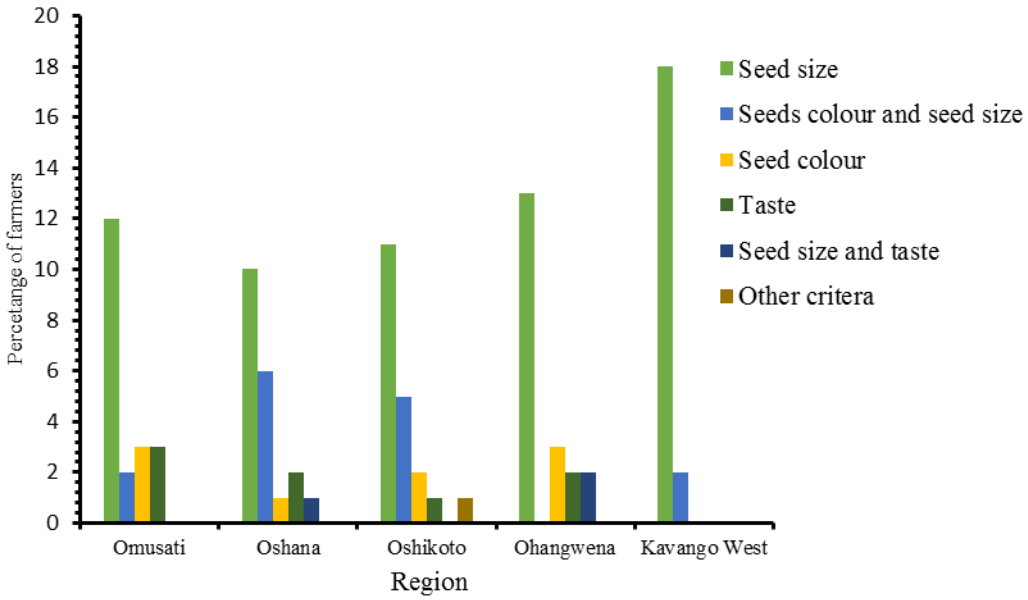


Fig. 1. Farmers seed selection by traits in the five regions in northern Namibia
Source: Author survey data (2019).

Seed coat colour preference

Seed colour is another attribute that farmers considered in all the regions one of the important bases used to select seeds for planting. Forty-five (45%) of the respondents chose seed colour trait as one of their selection criteria for planting seeds, where cream colour was the most selected colour (36%), followed by tan colour (33%) (Figure 2). The least selected colour was purple, liked by one farmer representing 2%. There was a significant association among the regions for seed colours, with the preferred colours being cream, tan, black, red and purple; these findings are similar to that of [21, 23]. Farmers indicated that the cream Bambara groundnut was most preferred, because of its sweet taste, less cooking time, marketability, preference for home consumption, uniform seed size. These results are in agreement with that obtained by [1]. The black colour was preferred by 18% of the farmers, who said

that black/dark -seeded cultivar is drought tolerant [24, 29]. The red colour was selected by 11% of farmers. The order for preference is cream, red and black, and this finding is similar to that reported by [4].

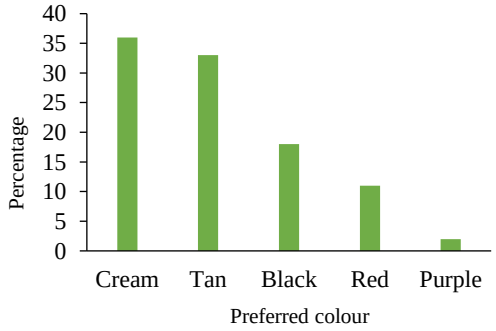


Fig. 2. Farmer-preferred seed colour in the study area
Source: Author survey data (2019).

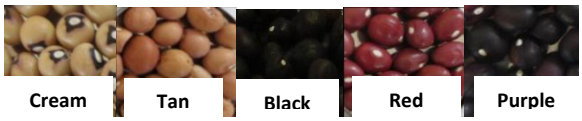


Photo 1. Preferred seeds coat colour of Bambara groundnuts in study area
Source: Author survey data (2019).

Improvement needs on preferred traits

Crop improvement of Bambara groundnut is one of the main objectives in the breeding of this crop.

The chi-square test detected a significant association (χ^2 = 34.783; $P \leq 0.000$) among farmers' responses towards the adoption of improved varieties. Ninety-two per cent (92%) of the Bambara groundnut farmers in the study area admitted that improved cultivars are needed. In exception of farmers (8%) from Kavango west who did not agree on cultivar improvement for the reason that Bambara groundnut is not their major crop. less than 55 kg/ha.

The chi-square test for trait showed that there was a highly significant association (χ^2 =79.334; $P \leq 0.000$) between regions and trait need improvements. (Table 7).

Forty-two per cent (42%) of the farmers indicated the need for Bambara groundnut yield improvement.

Every farmer needs to have high yielding varieties for every crop that is why yield scored the highest percentage that improvement is required. However, many farmers in the study area indicated that Bambara groundnut is low yielding.

Furthermore yield is a polygenic trait and can be influenced by environmental factors [26], including climate change [7] that may contribute to poor yield. A combination of yield, seed size, and insect tolerance was, to some degree, recommended by 16% of the farmers.

Table 7. Farmer-preferred traits to be improved in five northern regions of Namibia

Traits	Omusati	Oshana	Oshikoto	Ohangwena	Kavango West	Percentage
Yield (Y)	14	12	5	9	2	42
Seed size (SS)	2	1	2	2	1	8
Insect resistance (IR)	0	0	1	1	0	2
Drought tolerant (DT)	0	1	0	0	3	4
Y+ SS+Others	1	0	0	0	0	1
Y + SS	2	4	5	2	0	13
Y+ SS + IR	1	1	6	6	1	15
Yield + Others	0	1	0	0	1	2
IR + Others	0	0	0	0	4	4
Y+ IR+Others	0	0	0	0	1	1
SS +IR	0	0	1	0	0	1
Total	20	20	20	20	13	93
χ^2						79.334[a]
df						40
P-value						0.00

Source: Author survey data (2019).

Production constraints

The Bambara groundnut farmers' production constraints varied significantly across the regions studied. Production constraints were ranked according to the farmers' responses. Farmers constraints on Bambara groundnut

production varied significantly (χ^2 = 142.616; P < 0.036) across the regions. Results indicated that the main challenges were insects (26%), especially aphids and termites, low yield, use of unimproved varieties and other constraints including flooded field, squirrels, and rodents (Figure 3).

The low yield caused by insect pests usually destroyed pods and leaves, Similar results were reported by Ibrahim et al. (2018) in Western Niger [12].

Other causes of low yield reported by farmers included floods, squirrel and rodents, and these findings were in agreement with those of [20].

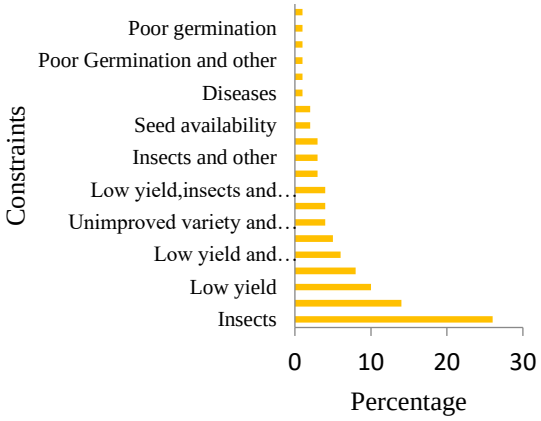


Fig. 3. Constraints faced by farmers in the production of Bambara groundnut in study area
Source: Author survey data (2019).

CONCLUSIONS

In five regions of northern Namibia, more women than men were involved in Bambara groundnut farming. The farmers' most preferred traits were seed size, seed coat colour, early maturity, high yield and drought tolerance. Farmers preferred cultivars included Olunya, Okaongoti, Engowa, Okambishi, and Egogani, whose names may have been derived from their seed colours and production levels. Most farmers sourced Bambara groundnut seeds from the previous harvest or informal markets. The formal seed production and marketing of Bambara groundnut need to be created and improved. The organisations that are researching on underutilised crops need to do more research on improvement to incorporate preferred traits of farmers and consumers and commercialise the crop.

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